

Bio Engineering (BIOE)

Courses

BIOE 020 Bioengineering Sophomore Research Seminar 1 Credit

Exposure to opportunities for on-campus research in bioengineering. Review of current literature on bioengineering topics through written reports and/or oral presentations. Preparation of written research proposal, including definition of topic, objectives, methodologies, research plans, and expected impact.

BIOE 025 Computer-aided Design for Bioengineers 0,3 Credits

Introduction to computer-aided design and analysis using SolidWorks software. Best design practices and hands-on experience in building parts, assemblies, and creating technical 2D drawings. Applications important in the medical product industry, such as diagnostic and clinical equipment, surgical tools, implants, drug delivery systems, and pharmaceutical packaging systems.

BIOE 110 Elements of Bioengineering 0,4 Credits

An introduction to the fields of biotechnology and biomedical engineering. The areas include biomechanics, biomaterials, bioinstrumentation, medical imaging, rehabilitation engineering, biosensors, biotechnology and tissue engineering.

Prerequisites: (BIOS 041 and BIOS 042)

BIOE 210 Introduction to Engineering Physiology 0,4 Credits

Mammalian physiology for bioengineering students, with an emphasis on control mechanisms and engineering principles. Basic cell function; biological control systems; muscle; neural; endocrine, circulatory, digestive, respiratory, renal, and reproductive systems; regulation of metabolism and defense mechanisms. Includes laboratory work.

Prerequisites: (BIOS 041 and BIOS 042) and MATH 022

BIOE 211 (BIOC 211, ENGR 211, MAT 211, ME 211) Capstone Design Project I 3 Credits

Students work on teams, integrating knowledge and skills acquired in their prior course work, to design practical solutions to real-world problems, typically in collaboration with industry, entrepreneurs, faculty, or campus departments. Teams perform in-depth engineering design while considering engineering standards and the project business case. Constraints, including technical, financial, environmental, societal, supply chain, regulatory, and others are considered throughout. Teams produce written reports, oral presentations, and prototypes appropriate for the project.

Prerequisites: BIOE 110 and BIOE 210 and (CHE 031 or MECH 003 or ECE 081)

Can be taken Concurrently: BIOE 210

BIOE 212 (BIOC 212, ENGR 212, MAT 212, ME 212) Capstone Design Project II 2 Credits

Students continue developing their solutions from BIOE 211 through prototype fabrication and testing, iteration, and failure mode analysis. New information about the project, as well as new knowledge, standards, and constraints, may be identified, considered and integrated into the solution. Teams are expected to produce a final project-specific prototype, an implementation plan appropriate to the project, as well as related business case financial models. Additional deliverables include written reports and presentations.

Prerequisites: BIOE 211 and BIOE 225

Can be taken Concurrently: BIOE 225

BIOE 225 GMP Good manufacturing practice and regulatory affairs for bioengineers 1 Credit

Review of the principles of the Food and Drug Administration including its history, mission and applied regulations. Understanding of how the FDA works with industry and is integral to the development of new products and technologies. Review and critique of case studies in various parts of the biomedical industry to see how FDA regulations are applied. Validation and analysis of products using failure mode analysis.

Prerequisites: BIOE 110

BIOE 226 Ethics in Bioengineering Practice 1 Credit

Introduction to ethical principles and role of critical thinking in ethical decision-making. Analysis of contemporary issues in bioengineering practice. Topics include biomedical device risk and failure, ethics of clinical trials, animal research, human enhancement, and research conduct.

BIOE 242 Bioengineering Research 1-4 Credits

Research on a topic chosen by students, with a faculty advisor typically from the three bioengineering tracks (biopharmaceutical engineering, bioelectronic/biophotonics or biomechanics and biomaterials). Independent meetings with advising professor will track progress. Includes written reports and/or oral presentations. Consent of instructor required.

Repeat Status: Course may be repeated.

BIOE 246 Bioengineering Thermodynamics 0,4 Credits

Engineering thermodynamics principles and their application to biological systems. Fundamental thermodynamics concepts, first and second law principles, conservation laws, properties of pure substances and biochemical mixtures under physiological conditions, energy conversion systems, thermodynamic aspects of biological processes.

Prerequisites: PHY 011 and MATH 022 and CHM 031

Can be taken Concurrently: CHM 031

BIOE 247 Biological Fluid Mechanics 0,4 Credits

Fluid and mass transport and their applications in biological systems. Mass conservation. Momentum and energy balances in fluid flow. Incompressible fluid flow with inviscid and viscous applications. Dimensional analysis. Fluid flow in pipes and porous media. Diffusion and convection.

Prerequisites: MATH 205

BIOE 257 Biomechanics 3 Credits

Overview of biomechanics. Application of fundamental laws of mechanics to biological systems. Systems examined include: strength of materials, biomechanics of cells, biomechanical analysis of tissues, rigid body kinematics, microstructure of materials and resultant mechanical properties, concepts of force and mechanics of rigid and deformable bodies, and failure processes of implantable biomaterials/devices. Exposure to current research in the field.

Prerequisites: MAT 033 and MECH 003 and MATH 205

Can be taken Concurrently: MATH 205

BIOE 290 Bioengineering Thesis 1-3 Credits

Thesis, guided by a faculty advisor, based on research and/or design projects. Independent meetings with advising professor to track progress. Consent of instructor required.

Prerequisites: BIOE 242 or TE 212

BIOE 300 Apprentice Teaching 1-4 Credits

Repeat Status: Course may be repeated.

BIOE 307 (CSE 307) Structural Bioinformatics 3 Credits

Computational techniques and principles of structural biology used to examine molecular structure, function, and evolution. Topics include: protein structure alignment and prediction; molecular surface analysis; statistical modeling; QSAR; computational drug design; influences on binding specificity; protein-ligand, -protein, and -DNA interactions; molecular simulation, electrostatics. Tutorials on UNIX systems and research software support an interdisciplinary collaborative project in computational structural biology. Credit will not be given for both CSE 307 and CSE 407. Must have junior standing or higher.

Prerequisites: BIOS 120 or CSE 109 or CHM 113 or MATH 231

BIOE 308 (CSE 308) Bioinformatics: Issues and Algorithms 3 Credits

Computational problems and their associated algorithms arising from the creation, analysis, and management of bioinformatics data. Genetic sequence comparison and alignment, physical mapping, genome sequencing and assembly, clustering of DNA microarray results in gene expression studies, computation of genomic rearrangements and evolutionary trees. Credit will not be given for both BIOE 308 (CSE 308) and BIOE 408 (CSE 408). No prior background in biology is assumed.

Prerequisites: CSE 017

Attribute/Distribution: ND

BIOE 310 Advanced Engineering Physiology 3 Credits

An in-depth examination of human physiological processes using a quantitative, model-oriented approach. Organ systems examined include the nervous, musculoskeletal, cardiovascular, respiratory, renal, immune, and endocrine systems. Mathematical models, computer simulations, and engineering analyses will be used to describe the performance of human organ systems and to study physiological processes.

Prerequisites: MATH 205 and BIOE 210

BIOE 311 (MAT 311) Introduction to Biomaterials 3 Credits

Application of materials science and engineering principles to biomedical materials with a focus on polymers, ceramics, and metals. Synthesis and fabrication of biomaterials, structure-property-function relationships related to biocompatibility and bioactivity; nano- to macro-scale characterization; material-tissue interactions; and applications of biomaterials including implants, devices, drug delivery, tissue engineering and regenerative medicine.

Prerequisites: MAT 033

BIOE 315 (ME 315) Bioengineering Statistics 3 Credits

Advanced methods in probability and statistics applied to bioengineering problems focusing on modeling and data analysis. Topics include the following: types of data, types of distributions, parametric and nonparametric analyses, goodness-of-fit, regression, power analysis, and multivariate analysis, life models, simulation, cluster analysis, and Bayesian statistics. Special emphasis is placed on projects and case studies.

Prerequisites: MATH 231

BIOE 316 (ME 316) Introduction to Force Spectroscopy 3 Credits

Fundamentals of major force spectroscopy methods, including atomic force microscopy, optical tweezers, and magnetic tweezers. Principles of force measurement, force calibration, and signal and noise. Applications to the mechanical properties of biomaterials, such as polymer elasticity, protein folding, nanoindentation, and structural transitions in macromolecules. Closed to students who have taken BIOE 416.

Prerequisites: MECH 003

BIOE 318 (CHE 318, MAT 318) Soft Materials: Rheology and Characterization 3 Credits

Characterization of soft materials using rheological techniques. Fundamentals of rheology and rheological characterization applied to materials such as polymers, glassy liquids and polymeric gels. Closed to students who have taken CHE/BIOE/MAT 418. Instructor permission or graduate status required.

BIOE 320 (CSE 320) Biomedical Image Computing and Modeling 3 Credits

Biomedical image modalities, image computing techniques, and imaging informatics systems. Understanding, using, and developing algorithms and software to analyze biomedical image data and extract useful quantitative information: Biomedical image modalities and formats; image processing and analysis; geometric and statistical modeling; image informatics systems in biomedicine. Credit will not be given for both BioE 320 and BioE 420.

Prerequisites: (MATH 205 or MATH 043) and CSE 017

Attribute/Distribution: ND

BIOE 321 Biomolecular & Cellular Mechanics 3 Credits

Mechanics and physics of the components of the cell, ranging in length scale from fundamental biomolecules to the entire cell. The course covers the mechanics of proteins and other biopolymers in 1D, 2D, and 3D structures, cell membrane structure and dynamics, and the mechanics of the whole cell.

Prerequisites: MATH 205 and MATH 231 and PHY 022 and (PHY 013 or PHY 021 or PHY 023)

BIOE 324 (MAT 324) Introduction to Organic Biomaterials 3 Credits

Property, characterization, fabrication and modification of organic materials for biomedical and biological applications; host responses to biomaterials on the molecular, cellular and system level; general introduction to biosensors, drug delivery devices and tissue engineering.

Prerequisites: BIOE 110

BIOE 325 (MAT 325) Inorganic Biomaterials 3 Credits

Fabrication methods for biomedical implants and devices. Selection of metals and ceramics with specific bulk and surface physical as well as chemical properties. The role of materials chemistry and microstructure. Biocompatibility. Case studies (dental and orthopedic implants, stents, nonporous ceramic filters for kidney dialysis).

Prerequisites: MAT 033

BIOE 326 (MAT 326) Biomimetic and Bio-enabled Materials 3 Credits

The structure, function, properties and use of biopolymers, biocomposites, and biominerals. Biomimetic materials design, including colloids, interfaces, macromolecules, and applications of such materials. Environmental and ethical considerations, such as degradation products when using biomimetic materials. Closed to students who have taken MAT 426 (BioE 426).

Prerequisites: MAT 033 or BIOE 110

Attribute/Distribution: ND

BIOE 331 Integrated Bioelectronics/Biophotonics Laboratory 2 Credits

Experiments in design and analysis of bioelectronics circuits, micropatterning of biological cells, micromanipulation of biological cells using electric fields, analysis of pacemakers, instrumentation and computer interfaces, ultrasound, optic, laser tweezers and advanced imaging and optical microscopy techniques for biological applications.

Prerequisites: (ECE 081 or PHY 190) and (PHY 013 or PHY 021 or PHY 023) and PHY 022 and ECE 121 and ECE 123

Can be taken Concurrently: ECE 121, ECE 123

BIOE 339 Neuronal Modeling and Computation 3 Credits

Neuroscience in a computational, mathematical, and engineering framework. Literature surveys and case studies with simulations. Computational aspects of information processing within the nervous system by focusing on single neuron modeling. Single neurons and how their biological properties relate to neuronal coding. Biophysics of single neurons, signal detection and signal reconstruction, information theory, population coding and temporal coding.

Prerequisites: ENGR 010 and MATH 205

BIOE 341 (CHE 341) Biotechnology I 3 Credits

Applications of material and energy balances; heat, mass, and momentum transfer; enzyme and microbial kinetics; and mathematical modeling to the engineering design and scale-up of bio-reactor systems. Closed to students who have taken CHE 441 (BIOE 341 and BIOE 441).

Prerequisites: MATH 205 and CHE 031 and (CHM 031 or CHM 041)

BIOE 342 (CHE 342) Biotechnology II 3 Credits

Engineering design and analysis of the unit operations used in the recovery and purification of products manufactured by the biotechnology industries. Requirements for product finishing and waste handling will be addressed. Closed to students who have taken CHE 442 (BIOE 342 and BIOE 442).

Prerequisites: MATH 205 and CHE 031 and (CHM 031 or CHM 041)

BIOE 343 Integrated Biotechnology Laboratory 0,3 Credits

Biosafety, sterilization, media formulation, biochemical and enzyme assays, recombinant DNA technique, protein and DNA isolation and purification, for microbial fermentation and animal cell culture. Integration of biotechnology techniques for biopharmaceutical production. Consent of instructor required.

Prerequisites: BIOE 110 and (CHE 341 or BIOE 341)

BIOE 344 (CHE 344) Molecular Bioengineering 3 Credits

Kinetics in small systems, stochastic simulation of biochemical processes, receptor-mediated adhesion, dynamics of ion-channels, ligand binding, biochemical transport, surface Plasmon resonance, DNA microarray design, and chemical approaches to systems biology. Senior standing in BIOE.

Prerequisites: (MATH 205 and MATH 231)

BIOE 345 (CHE 345) Quantitative Biology 3 Credits

Basic concepts in molecular and cellular biology as well as biochemistry. Connects these to engineering principles to (1) develop a quantitative understanding of biological systems and (2) understand how modern engineering uses applications of methods and principles in biology. Topics include quantity and length scales in biology, use of statistical mechanics to describe phenomena such as microstates and ligand receptor binding, and application of chemical reaction kinetics to describe biochemical reactions. Closed to students who have taken BIOE 445.

Prerequisites: MATH 205

BIOE 348 Cardiovascular Bioengineering 3 Credits

Review of current and emerging trends in cardiac and vascular device development. Topics include cardiovascular anatomy and physiology principles, molecular and systemic basis of cardiovascular pathologies, techniques for diagnosis and surgical management of select disease manifestations. Medical, bioengineering and biologic parameters influencing the design and selection of interventional devices and endovascular prosthetics, as well as the engineering tools necessary for their evaluation. Consideration of factors contributing to device failure and state of the art in experiments and human clinical trials.

Prerequisites: BIOE 210 and BIOE 247

BIOE 349 Metabolic Engineering 3 Credits

Quantitative perspective of cellular metabolism and biochemical pathways. Methods for analyzing stoichiometric and kinetic models, mass balances, flux in reaction networks, and metabolic control. Solving problems using advanced mathematics and computer programming.

Prerequisites: MATH 205

BIOE 350 Special Topics 1-4 Credits

Special topics of study in bioengineering. Permission of Instructor.

Repeat Status: Course may be repeated.

BIOE 357 Integrated Biostructural Mechanics Laboratory 3 Credits

Experimental manipulation and analysis of mammalian cells, with a focus on the biomechanical properties of cells, the interface of living and non-living materials, and on bioengineering applications. Experimental techniques include mammalian cell culture, advanced microscopy techniques, preparation of bioactive substrates, microfluidic device fabrication, micropatterning of cells and cell growth in 3D matrices. Consent of instructor required.

Prerequisites: BIOE 110

BIOE 358 Biomechanics 3 Credits

Applications of mechanics to study behavior of anatomical structures and biological tissues of the musculoskeletal system. Specific topics include structure and function of biological tissues, mechanical properties of biological tissues, and analysis of specific tissues (i.e. bone, muscle, and soft connective tissues).

Prerequisites: MECH 003

Can be taken Concurrently: MECH 003

BIOE 359 Biomechanics Laboratory 1 Credit

Applications of mechanics to study behavior of anatomical structures and biological tissues of the musculoskeletal system. Specific topics include structure and function of biological tissues, mechanical properties of biological tissues, and analysis of specific tissues (i.e. bone, muscle, and soft connective tissues).

Prerequisites: MECH 003 and BIOE 358

Can be taken Concurrently: MECH 003, BIOE 358

BIOE 363 (CHE 363) Numerical Methods for Scientists and Engineers 3 Credits

Introduction to numerical methods in science and engineering. Expose students to the numerical solution of a variety of commonly encountered problems, enhance their numerical programming skills, and provide a broad base on which to build more specialized knowledge of computational methods. Topics include solution of linear and nonlinear sets of algebraic equations, linear and logistic regression, ordinary differential equations, Fourier analysis, eigenvalues, partial differential equations by finite difference and finite element methods.

Prerequisites: MATH 205

BIOE 366 (ECE 366) Neural Engineering 3 Credits

Neural system interfaces for scientific and health applications. Basic properties of neurons, signal detection and stimulation, instrumentation and microfabricated electrode arrays. Fundamentals of peripheral and central neural signals and EEG, and applications such as neural prostheses, implants and brain-computer interfaces. Closed to students who have taken BIOE 466, ECE 366, or ECE 466.

Prerequisites: ECE 081

BIOE 367 (CHE 367) Engineering in Medicine 3 Credits

Introduction to the physical basis of disease. Discussion of biomolecular strategies to overcome these changes. Topics include drug delivery, targeting, and tissue engineering, with a focus on infectious disease, cancer, cardiovascular disease, and neurodegenerative disease. Closed to students who have taken CHE 467 (BIOE 367 and BIOE 467).

BIOE 368 (ECE 368) Introduction to Biophotonics and Optical Biomedical Imaging 3 Credits

Optical principles, techniques, and instruments used in biomedical research and clinical medicine. Fundamental concepts of optical imaging and spectroscopy systems, and details of light-tissue interaction. Commercial devices and instruments, as well as novel optical imaging technologies in development. Closed to students who have taken BIOE 468, ECE 368, or ECE 468.

Prerequisites: ECE 202 or PHY 212

BIOE 369 (CHE 369) Advanced Topics in Regulatory Affairs 3 Credits

Regulatory requirements for the development and manufacture of 21st century medical products. Current challenges and innovative technologies in pharmaceuticals and medical devices. Topics include combination products, biosimilars, cell therapeutics, mobile medical applications, 3D-printed products, big data in healthcare, new approaches to process validation. Closed to students who have taken BIOE/CHE 469.

Prerequisites: BIOE 225

BIOE 370 (CHE 370) The Engineering of Brewing, Winemaking, and Distilling 0,3 Credits

An open-ended and experiential exploration of the engineering principles required for the brewing of beer, winemaking, and distilling of spirits.

Prerequisites: (BIOE 341 or CHE 211) and (BIOE 246 or CHE 212)

BIOE 372 Drug Delivery and Nanomedicine 3 Credits

Fundamental principles of controlled drug delivery, including drug release systems and their mechanisms, physiological barriers, and routes of delivery. Impact of nanotechnology on designing advanced drug delivery technologies, such as targeted drug therapies, controlled release systems for tissue engineering/ regenerative medicine, and non-viral gene delivery systems. Credit will not be given for both BIOE 372 and 472.

Prerequisites: MATH 022 and CHM 031

BIOE 373 Tissue Engineering and Regenerative Medicine 3 Credits

Introduction to tissue engineering and regenerative medicine principles used to develop potential treatments for broad range of injuries and pathologies. Building blocks for engineering tissues, including cells, biomaterials, and bioactive cues. Criteria for selection of cell source, scaffold design and fabrication methods, and tools for control of cellular microenvironment. Consideration of economic, social, and ethical aspects of tissue engineering. Credit will not be given for both BIOE 373 and BIOE 473.

Prerequisites: CHM 031

BIOE 383 Introduction to Bioimaging and Microscopy 0,3 Credits

Principles, technologies, and instrumentation of numerous modern imaging modalities, including X-ray, computed tomography, magnetic resonance imaging, ultrasound, and positron emission tomography. Fundamental concepts to advanced systems and their applications. Hands-on experience with advanced research microscopes and exposure to cutting edge imaging instrumentation. Discussion of articles in current literature. Credit will not be given for both BIOE 383 and BIOE 483.

Prerequisites: PHY 021

BIOE 407 (CSE 407) Structural Bioinformatics 3 Credits

Computational techniques and principles of structural biology used to examine molecular structure, function, and evolution. Topics include: protein structure alignment and prediction; molecular surface analysis; statistical modeling; QSAR; computational drug design; influences on binding specificity; protein-ligand, -protein, and -DNA interactions; molecular simulation, electrostatics. This course, a version of 307 for graduate students, requires advanced assignments and a collaborative project. Credit will not be given for both BIOE 307 and 407. Consent of instructor required.

BIOE 408 (CSE 408) Bioinformatics: Issues and Algorithms 3 Credits

Computational problems and their associated algorithms arising from the creation, analysis, and management of bioinformatics data. Genetic sequence comparison and alignment, physical mapping, genome sequencing and assembly, clustering of DNA microarray results in gene expression studies, computation of genomic rearrangements and evolutionary trees. This course, a version of 308 for graduate students requires advanced assignments. Credit will not be given for both BIOE 308 (CSE 308) and BIOE 408 (CSE 408). No prior background in biology is assumed.

Prerequisites: CSE 017 or CSE 018

Attribute/Distribution: ND

BIOE 409 Bioengineering Applications in Machine Learning 3 Credits

This course is a graduate-level version of BIOC 309. While the lecture content will be the same as the 300-level course, students enrolled in BIOC 409 will have more advanced assignments. Closed to students who have taken BIOC 309.

BIOE 410 Advanced Engineering Physiology 3 Credits

This course is a graduate-level version of BIOE 310. While the lecture content will be the same as the 300-level course, students enrolled in BIOE 410 will have more advanced assignments. Closed to students who have taken BIOE 310.

BIOE 411 (MAT 411) Introductions to Biomaterials 3 Credits

Application of materials science and engineering principles to biomedical materials with a focus on polymers, ceramics, and metals. Synthesis and fabrication of biomaterials, structure-property-function relationships related to biocompatibility and bioactivity; nano- to macro-scale characterization; material-tissue interactions; and applications of biomaterials including implants, devices, drug delivery, tissue engineering and regenerative medicine. MAT 411 will require project-based study. Credit will not be given for both MAT 311 and MAT 411.

Prerequisites: MAT 033

BIOE 415 Bioengineering Statistics 3 Credits

Advanced methods in probability and statistics applied to bioengineering problems focusing on modeling and data analysis. Topics include the following: types of data, types of distributions, parametric and nonparametric analyses, goodness-of-fit, regression, power analysis, and multivariate analysis, life models, simulation, cluster analysis, and Bayesian statistics. Special emphasis is placed on projects and case studies. Credit can not be received for both BIOE/ME 315 and BIOE 415.

BIOE 416 Introduction to Force Spectroscopy 3 Credits

This course is a graduate version of BIOE 316 (ME 316). While the lecture content will be the same as the 300-level course, students in the 400-level class will be expected to complete more advanced assignments. Closed to students who have taken BIOE 316 (ME 316).

BIOE 417 (CHE 417, MAT 417) Soft Materials: Mechanics and Physics 3 Credits

Physical and mechanical behavior of soft materials such as gels, foams, rubbers, soft adhesives, and most biological tissue. Large strain kinematics, stress measures, constitutive relations from the molecular and continuum points of view, and application to problems such as cavitation, creasing, thin structures, fracture, adhesion, surface stress, and electroactive materials.

Prerequisites: CHE 452 or ENGR 452

BIOE 418 (CHE 418, MAT 418) Soft Materials: Rheology and Characterization 3 Credits

See the course description listed for CHE/BIOE/MAT 318. In order to receive 400-level credits, the student must do an additional, more advanced term project, as defined by the instructor at the beginning of the course. Closed to students who have taken CHE/BIOE/MAT 318.

BIOE 420 (CSE 420) Biomedical Image Computing and Modeling 3 Credits

Biomedical image modalities, image computing techniques, and imaging informatics systems. Understanding, using, and developing algorithms and software to analyze biomedical image data and extract useful quantitative information: Biomedical image modalities and formats; image processing and analysis; geometric and statistical modeling; image informatics systems in biomedicine. This course, a graduate version of BioE 320, requires additional advanced assignments. Credit will not be given for both BioE 320 and BIOE 420.

Prerequisites: MATH 205 and CSE 109

Attribute/Distribution: ND

BIOE 421 (CHE 421) Biomolecular & Cellular Mechanics 3 Credits

Mechanics and physics of cell components, from fundamental biomolecules to the entire cell. The mechanics of proteins and other biopolymers in 1D, 2D, and 3D structures, cell membrane structure and dynamics, and the mechanics of the whole cell. This course is a graduate version of ChE 321 (BioE/Phy 321). The lecture content will be the same as in ChE 321 (BioE/Phy 321), but students enrolled in ChE 421 (BioE 421) will have more advanced assignments. Closed to students who have completed ChE 321 (BioE/Phy 321). Must have graduate standing.

BIOE 424 (MAT 424) Introduction to Organic Biomaterials 3 Credits

Property, characterization, fabrication, and modification of organic materials for biomedical and biological applications; host responses to biomaterials on the molecular, cellular, and system level; general introduction to biosensors, drug delivery, and tissue engineering. Graduate version of BioE 324 requiring additional assignments. Credit is not given for both BioE 324 (MAT 324) and BioE 424 (MAT 424).

Prerequisites: MAT 033

BIOE 425 (MAT 425) Inorganic Biomaterials 3 Credits

Fabrication methods for biomedical implant and devices. Selection of metals and ceramics with specific bulk and surface physical as well as chemical properties. The role of materials chemistry and microstructure. Biocompatibility. Case studies (dental and orthopedic implants, stents, nonporous ceramic filters for kidney dialysis). Graduate version of MAT 325; credit will not be given for both MAT 325 and MAT 425.

Prerequisites: MAT 033

BIOE 426 (MAT 426) Biomimetic and Bio-enabled Materials 3 Credits

This course is a graduate version of BIOE 326 (MAT 326). While the lecture content will be the same as the 300-level course, students enrolled in BIOE 426 (MAT 426) will have more advanced assignments. Closed to students who have taken BIOE 326 (MAT 326). Must have graduate standing in Bioengineering or Materials Science and Engineering.

Attribute/Distribution: ND

BIOE 439 (CHE 439) Neuronal Modeling and Computation 3 Credits

This course is a graduate version of BIOE 339 (CHE 339). While the lecture content will be the same as the 300-level course, students in the 400-level class will be expected to complete an independent term project. Closed to students who have completed BIOE 339 (CHE 339). Must have graduate standing in Bioengineering or Chemical Engineering.

BIOE 441 (CHE 441) Biotechnology I 3 Credits

See the course description listed for BioE 341. In order to receive 400-level credits, the student must do an additional, more advanced term project, as defined by the instructor at the beginning of the course. Closed to students who have taken BioE 341 (CHE 341).

BIOE 442 (CHE 442) Biotechnology II 3 Credits

See the course description listed for BIOE 342 (CHE 342). In order to receive 400-level credit, the student must do an additional, more advanced term project, as defined by the instructor at the beginning of the course. Closed to students who have taken BIOE 342 (CHE 342).

BIOE 445 (CHE 445) Quantitative Biology 3 Credits

This course is a graduate-level version of BIOE 345. While the lecture content will be the same as the 300-level course, students enrolled in BIOE 445 will have more advanced assignments. Closed to students who have taken BIOE 345.

BIOE 447 (CHE 447) Molecular Bioengineering 3 Credits

This course is a graduate version of CHE 344 (BioE 344). While the lecture content will be the same as the 300-level course, students enrolled in CHE 447 will have more advanced assignments. Closed to students who have completed BioE 344 (CHE 344).

BIOE 448 Cardiovascular Bioengineering 3 Credits

This course is a graduate-level version of BIOE 348. While the lecture content will be the same as the 300-level course, students enrolled in BIOE 448 will have more advanced assignments. Closed to students who have taken BIOE 448.

BIOE 449 (CHE 449) Metabolic Engineering 3 Credits

This course is a graduate version of BIOE 349. While the lecture content will be the same as the 300-level course, students enrolled in BIOE 449 (CHE 449) will have more advanced assignments. Closed to students who have completed BIOE 349. Must have graduate standing in Chemical Engineering or Bioengineering.

BIOE 450 Special Topics 1-3 Credits

Special topics of study in bioengineering. Permission of instructor.

BIOE 451 Bioengineering Research Projects 1-6 Credits

Bioengineering-related research projects, based upon faculty and student interest. Projects may involve interaction with industry or local communities. Department permission required. A maximum of 6 credits of BIOE 451 can be used toward degree requirements.

Repeat Status: Course may be repeated.

BIOE 452 (CHE 452, ENGR 452, ME 452) Mathematical Methods In Engineering I 3 Credits

Analytical techniques relevant to the engineering sciences are described. Vector spaces; eigenvalues; eigenvectors. Linear ordinary differential equations; diagonalizable and non-diagonalizable systems. Inhomogeneous linear systems; variation of parameters. Non-linear systems; stability; phase plane. Series solutions of linear ordinary differential equations; special functions. Laplace and Fourier transforms; application to partial differential equations and integral equations. Sturm-Liouville theory. Finite Fourier transforms; planar, cylindrical, and spherical geometries.

BIOE 453 Professional Development for Bioengineers 1 Credit

This course, designed for students enrolled in a Master's program in Bioengineering, provides the professional skills necessary to prepare students for full-time employment in industry, or alternatively, for enrollment in a doctoral program towards a research career. Topics covered include resume development, networking and interviewing skills, awareness of current and emerging professional opportunities, biomedical ethics, and technical/scientific communication.

BIOE 455 Scientific and Professional Communications for Bioengineers 3 Credits

Development and practice of critical reading skills through study of articles in the current bioengineering literature, including their societal, regulatory, and real-world context. Build capabilities in analytical and creative thinking and scientific communication, including best practices for presenting data for journal articles, writing research proposals, presenting professional talks and seminars, and understanding the manuscript and proposal review process. Formulate an individual development plan to guide technical and professional development, and provide a framework for communicating with advisers, mentors, and colleagues.

BIOE 456 (CHE 456) Stochastic Processes: Theory and Applications in Biology 3 Credits

Stochastic, or probabilistic, models of cellular processes and other biological systems to describe the inherent randomness of nature. Topics covered include theory and biological applications of Markov chains, the Master Equation, white noise and stochastic integrals, the Fokker-Planck Equation, and noise in gene expression. Some minimal experience in programming and/or Mathematica/Matlab.

Prerequisites: MATH 205

BIOE 463 (CHE 463) Numerical Methods for Scientists and Engineers 3 Credits

See the course description listed for ChE 363 (BIOE 363). This course is graduate version of ChE 363 (BIOE 363). The lecture content will be the same as ChE 363 (BIOE 363), but students enrolled in ChE 463 (BIOE 463) will have more advanced assignments. Closed to students who have taken ChE 363 (BIOE 363). Must have graduate standing or consent of the instructor.

BIOE 466 (ECE 466) Neural Engineering 3 Credits

Neural system interfaces for scientific and health applications. Basic properties of neurons, signal detection and stimulation, instrumentation and microfabricated electrode arrays. Fundamentals of peripheral and central neural signals and EEG, and applications such as neural prostheses, implants and brain-computer interfaces. Closed to students who have taken BIOE 366, ECE 366, or ECE 466. Students enrolled in the course at the 400-level must complete additional advanced assignments, as defined by the course instructor.

BIOE 467 (CHE 467) Engineering in Medicine 3 Credits

See the course description listed for CHE 367 (BIOE 367). In order to receive 400-level credits, the student must do an additional, more advanced term project, as defined by the instructor at the beginning of the course. Closed to students who have taken CHE 367 (BIOE 367), or BIOE 467.

BIOE 468 (ECE 468) Introduction to Biophotonics and Optical Biomedical Imaging 3 Credits

Optical principles, techniques, and instruments used in biomedical research and clinical medicine. Fundamental concepts of optical imaging and spectroscopy systems, and details of light-tissue interaction. Commercial devices and instruments, as well as novel optical imaging technologies in development. Closed to students who have taken BIOE 368, ECE 368, or ECE 468. Students enrolled in the course at the 400-level must complete additional advanced assignments, as defined by the course instructor.

BIOE 469 (CHE 469) Advanced Topics in Regulatory Affairs 3 Credits

This course is a graduate version of BIOE 369 (CHE 369). While the lecture content will be the same as the 300-level course, students enrolled in BIOE 469 (CHE 469) will have more advanced assignments. Closed to students who have taken BIOE/CHE 369.

BIOE 472 Drug Delivery and Nanomedicine 3 Credits

This course is a graduate-level version of BIOE 372. While the lecture content will be the same as BIOE 372, students enrolled in BIOE 472 will have more advanced assignments. Credit will not be given for both BIOE 372 and BIOE 472.

BIOE 473 Tissue Engineering and Regenerative Medicine 3 Credits

This course is a graduate-level version of BIOE 373. While the lecture content will be the same as BIOE 373, students enrolled in BIOE 473 will have more advanced assignments. Credit will not be given for both BIOE 373 and BIOE 473.

BIOE 483 Introduction to Bioimaging and Microscopy 0,3 Credits

This course is a graduate-level version of BIOE 383. While the lecture content will be the same as BIOE 383, students enrolled in BIOE 483 will have more advanced assignments. Credit will not be given for both BIOE 383 and BIOE 483.

BIOE 490 Thesis 1-6 Credits

Repeat Status: Course may be repeated.

BIOE 499 Dissertation 1-12 Credits